Generating Climate Benchmark Atmospheric Soundings Using GPS Radio Occultations

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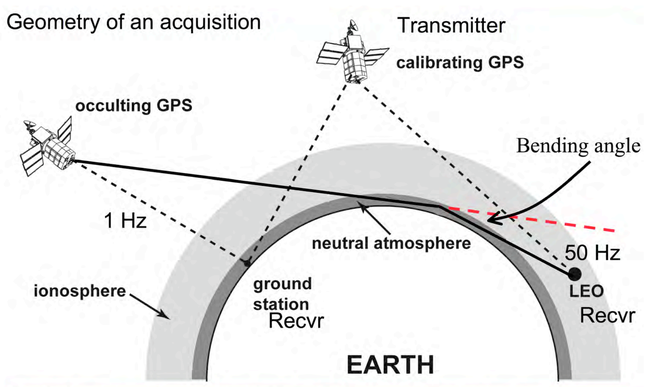
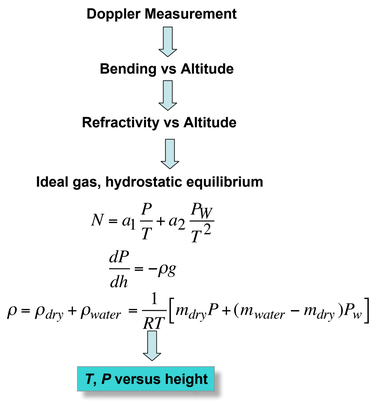
Abstract: The GPS radio occultation technique is described. Published and new validation results versus radiosonde are presented. We discuss remaining research and activities required to establish the SI-traceability of GPS RO temperature soundings on an operational basis. Finally, we present recent science data from GPS RO pointing to new results in climate science.

1.Technique





The GPS radio occultation method (GPS RO). The GPS receiver in low-Earth orbit measures the phase of the GPS transmissions from which we extract the Doppler shift of the transmitted signal caused by the atmospheric refractive index. The science data system at JPL produces profiles of temperature and pressure from the mid-troposphere to the stratosphere, and water vapor in the lower troposphere. Profiles have sub-km vertical resolution and are horizontally averaged over ~250 km.

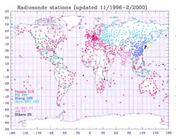
Density/water ambiguity: equation for refractive index includes contributions due to water vapor and atmospheric density. The contribution due to water vapor is negligible above ~7 km altitude. Water can be retrieved in the lower troposphere if temperature is provided from analyses (see attachment for error analysis details). These considerations are important for climate benchmarking.

All-weather: GPS signals are not impeded by humidity or clouds.

Geodetic infrastructure: CLARREO requires a robust space geodetic infrastructure to support GPS RO climate benchmark observations.

2.Validation versus radiosondes

Citation:
Kuo, Y.-H., W. S. Schreiner, J. Wang, D. L. Rossiter, and Y. Zhang (2005), "Comparison of GPS radio occultation soundings with radiosondes," Geophys. Res. Lett., 32, L05817, doi:10.1029/2004GL021443.

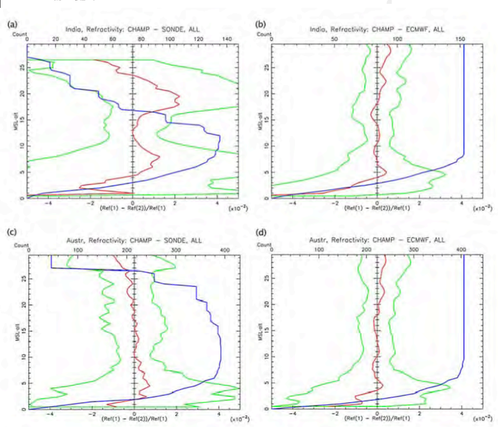


Geographic distribution of global radiosonde stations (total 852) colored by radiosonde types. The percentage given in legend is the percentage of stations used by each type of radiosonde.

Table 1. Mean Absolute Fractional Differences and Standard Deviation (S.D.) of Refractivity Between CHAMP RO Soundings and the Soundings From Five Different Types of Radiosonde Systems[a]

Region	Sonde Type	# of Matches	$\overline{\Delta N_{CR}}$/S.D. (%)	$\overline{\Delta N_{CE}}$/S.D. (%)
India	IM-MK3	87	0.82/3.2	0.15/1.0
Russia	Mars	1003	0.30/1.3	0.09/0.9
Japan	MEISEI	107	0.26/1.7	0.14/1.1
China	Shanghai	402	0.19/1.4	0.15/1.0
Australia	Vaisala	366	0.18/1.3	0.13/0.9

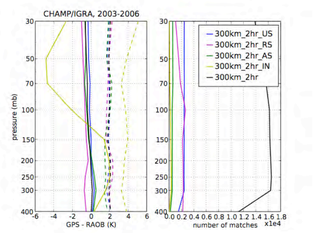
[a]The number of matches is computed as the average number of CHAMP – radiosonde ("CR") matches from 5 to 25 km. The corresponding differences between CHAMP RO soundings and the ECMWF analysis are designated as "CE".



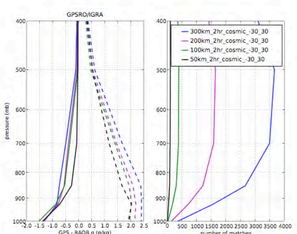
Fractional temperature error is ≈ fractional refractivity error (above 5 km altitude)

NOTE: all results in above column are from the cited publication

Recent comparisons GPS RO and IGRA radiosondes
Chi Ao, JPL

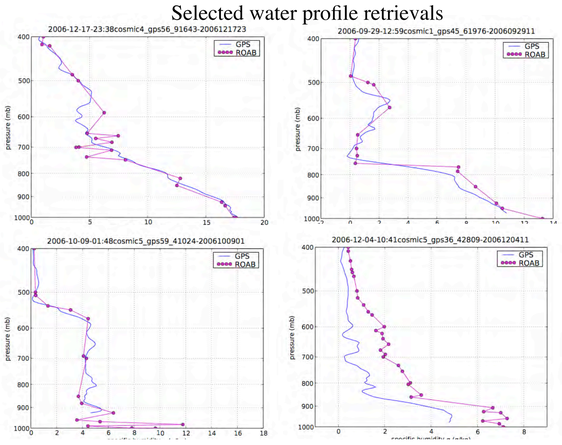


Temperature comparisons in various countries: mean and standard deviation of differences



Tropical water vapor retrievals: mean and standard deviation of differences

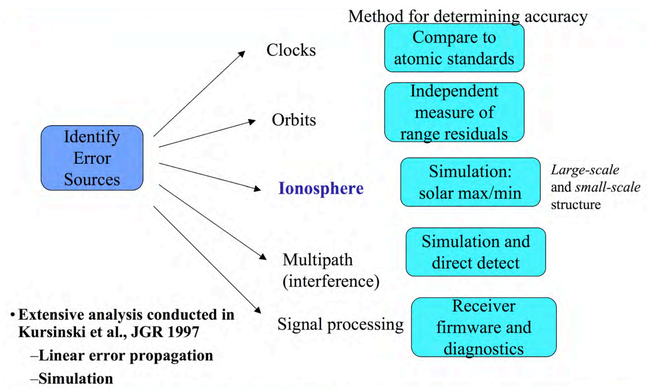
Selected water profile retrievals



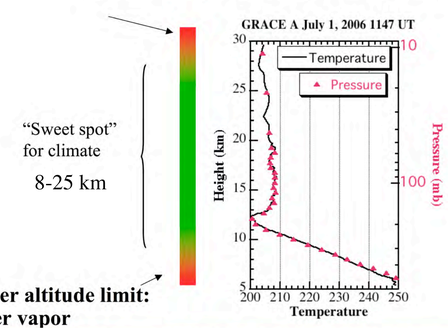
3. Climate goal: 0.1 K accuracy SI-traceable on-orbit

With GPS RO, this can be achieved between the altitudes of ~8-25 km

Detailed error analyses is necessary to establish SI-traceability

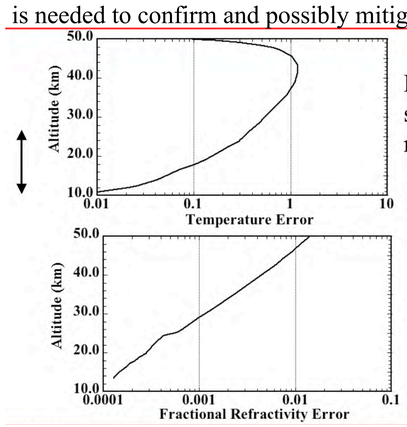


Upper altitude limit: low SNR, upper altitude initialization (temperature), ionosphere



Lower altitude limit: water vapor

Residual ionospheric delay error may cause bias of ~0.1 K between daytime solar maximum and minimum. Research is needed to confirm and possibly mitigate.



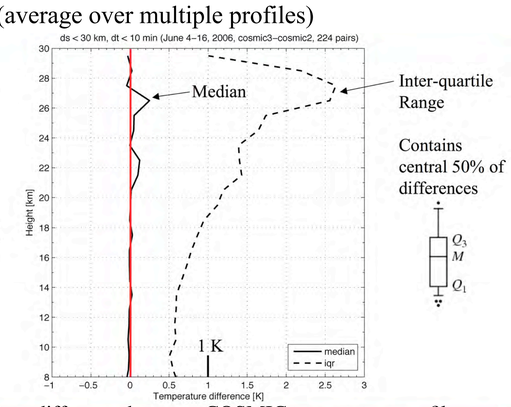
Method: ray-trace signal through a model ionosphere

From the solar maximum simulation of Kursinski et al. JGR, 1997

Encouraging results: COSMIC inter-comparisons demonstrate inter-satellite biases less than 0.1 K (average over multiple profiles)

COSMIC3 - COSMIC2

Window:
30 km
10 minutes
June 4-16, '06
224 pairs



Mean difference between COSMIC temperature profiles, satellite 3 minus satellite 2

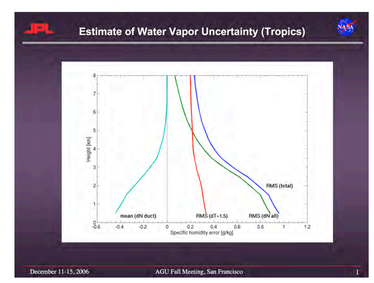
Needed Research:

- **Further investigation of selected error terms (ionosphere, orbit traceability to SI)**
- **SI-traceability not yet embedded in current processing systems**
- **Production engineering and documentation**

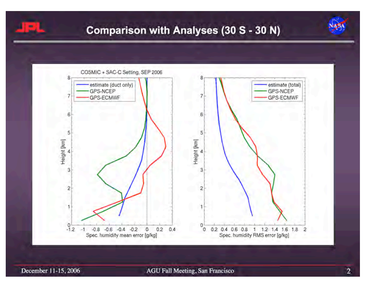
4. Science

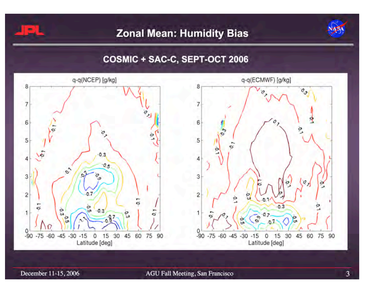
Tropical moisture retrievals and comparison to analyses ECMWF and NCEP

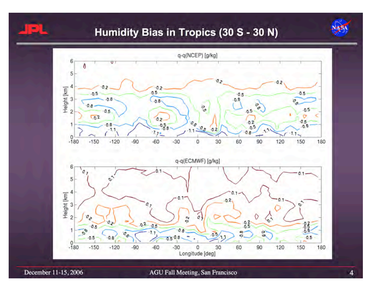
Presented at Fall AGU 2006, San Francisco CA



Chi Ao et al., JPL







Take-away Message:

- GPS RO is a powerful tool for climate benchmark observations
- Further work is required to establish SI-traceability with existing systems
- New science applications are being developed

Acknowledgements:
The research in this poster was conducted by JPL/Caltech under contract to NASA.

A robust geodetic infrastructure such as that provided by the International GNSS Service (IGS) is essential for successful execution of this research.